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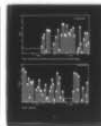
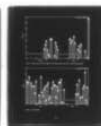
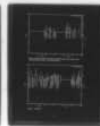
NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA  
OCCURRENCE OF SCINTILLATION OF UHF SATCOM SIGNALS AT GUAM FROM --ETC(U)  
SEP 78 M R PAULSON  
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**Technical Report 328**

**OCCURRENCE OF SCINTILLATION OF  
UHF SATCOM SIGNALS AT GUAM FROM  
MID-MARCH TO MID-AUGUST 1978**

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MR Paulson

7 September 1978

Prepared for  
Office of Naval Research

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NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA 92152

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AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

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Commander

HL BLOOD

Technical Director

#### ADMINISTRATIVE INFORMATION

Work was accomplished by personnel of the Environmental Sciences Department under 61153N, RR0320801, NOSC 532 MP 34.

#### ACKNOWLEDGEMENTS

The satellite signal amplitude recordings used in this report were made by personnel at the Naval Communications Area Master Station (NAVCAMS) on Guam under the direction of CWO Dan Thomas.

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## OBJECTIVE

Obtain longer term statistics on equatorial scintillation of uhf satellite signals.

## RESULTS

1. The occurrence of significant scintillation at Guam has greatly increased over that observed during the 1976 solar activity minimum even though we are only about 2 years into a cycle of increasing solar activity.
2. The occurrence of scintillation observed shows a broad maximum with extensive scintillation occurring from mid-March to mid-August rather than being limited to a short period around the equinox.
3. Scintillation can frequently cause uhf satellite communications outages of 6 to 8 hours a night with occasional outages of 10 hours or more.
4. While a year-to-year dependence of the occurrence of scintillation on solar activity can be shown using averaged data for the same time of year, seasonal variations in the occurrence may conceal this dependence when using data for a single year.

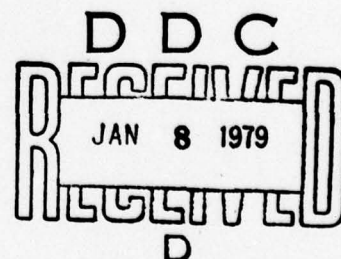
## RECOMMENDATIONS

Equatorial scintillation measurements should be made at Guam for a longer period of time, at least a year, to get information on the seasonal variation in occurrence and intensity. The data should be recorded on magnetic tape so that a detailed statistical analysis can be made.

These measurements should be made on both the Indian Ocean and the Pacific Ocean GAFILLER/MARISAT satellites at both the uhf and the L-band frequencies. This would provide two elevation angles - 9 and 50 degrees - and two frequencies - 257.55 and 1541.5 MHz.

The results of these measurements could be used to develop a statistical model of the equatorial scintillation of satellite signals. This model could be used to predict the probability of the occurrence of significant equatorial scintillation at any given time and the extent to which satellite communications would be adversely affected.

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## INTRODUCTION

Scintillation of radio waves from a satellite is caused by irregularities in the electron density in the ionosphere. These result in irregularities in the ionospheric refractive index which cause refraction or diffraction of the radio wave as it passes through the ionosphere. The irregular wave front emerging from the ionosphere propagates to the ground where a standing wave pattern, or diffraction pattern, is set up. This pattern has regions of signal stronger than the undisturbed signal and regions of weak or no signal at all. As the irregularities in the ionosphere drift and change, the diffraction pattern moves past a receiving antenna causing the fluctuating signal intensity measured by a receiver; figure 1 shows an example of this. Signal enhancements of up to 10 dB occur and signal fades greater than 30 dB are regularly observed at frequencies around 250 MHz.

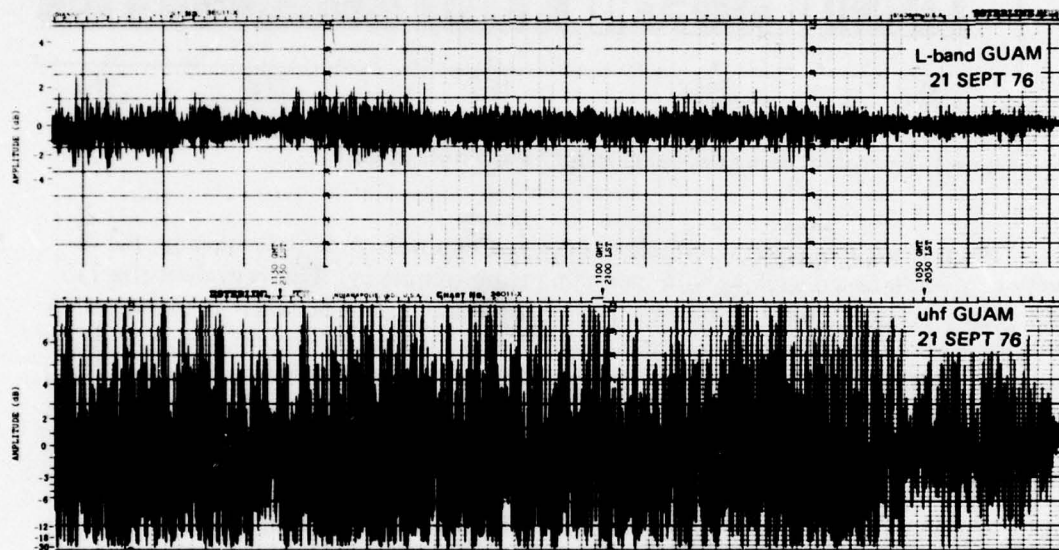


Figure 1. Chart record reproduction showing L-band and uhf scintillation fading.

This scintillation fading has a very disruptive effect on uhf satellite communications. Figure 2 shows a sample of about 2 hours of data error rates measured at 257 MHz at a 2400 b/s rate. Error rates of up to 30 percent occurred regularly even though the undisturbed signal-to-noise ratio was about 30 dB.

Since the propagation paths between a satellite and a ground terminal are reciprocal, scintillation also affects the up link when transmitting to the satellite at uhf. For this reason, during equatorial scintillation, the satellite sees a uhf signal that may be fluctuating in intensity by as much as 40 dB.



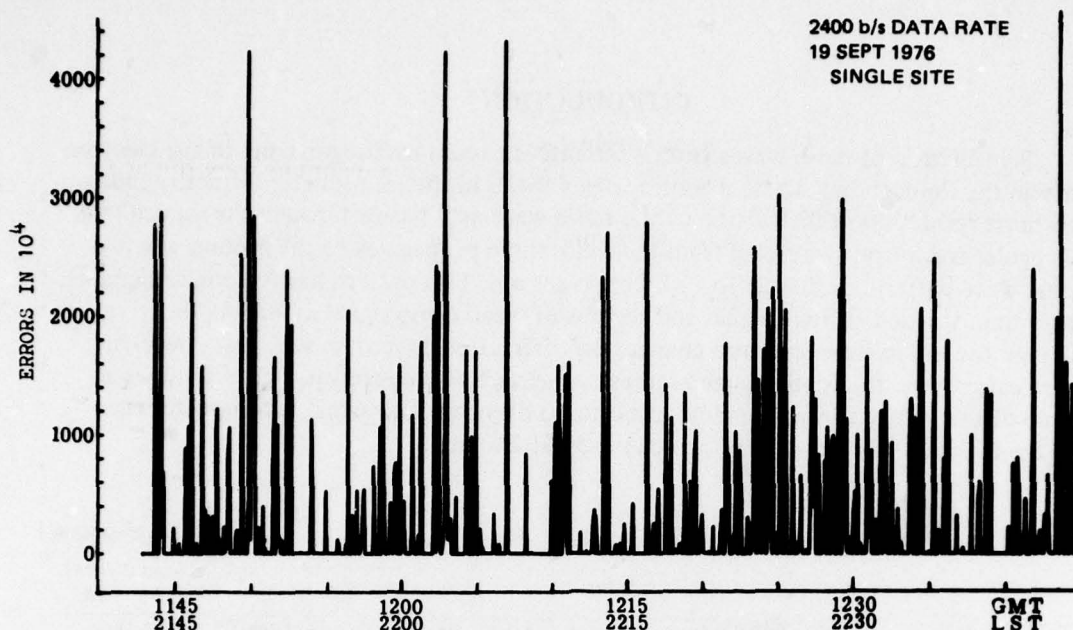


Figure 2. Example of error rates measured for a single receiver site.

Because the ionospheric refractive index is a function of radio frequency, the intensity of scintillation decreases with increasing radio frequency. This is evident (fig 1) in the record labeled L-band. However, this example should not be taken as an indication of the limit of scintillation intensity at L-band. The occurrence, duration, and intensity of equatorial scintillation vary directly with solar activity. Since 1976 (when the data [fig 1] were recorded) was a minimum in the solar cycle, the scintillation activity and intensity can be expected to increase at the L-band as well as at uhf as solar activity increases in this new cycle.

The Naval Ocean Systems Center (NOSC) has been investigating equatorial scintillation and its effects on satellite communications since 1970.<sup>1,2</sup> These investigations consist of measurements made in 1970, 1971, and 1972 for about a month each time around the fall equinox and in 1976 from July through November. While much was learned about equatorial scintillation, little information was obtained on how much of the year the scintillation might be expected to disrupt uhf satellite communications. Personnel at the Naval Communications Area Master Station (NAVCAMS), Guam, have undertaken the monitoring of uhf broadcast signals from both the Pacific Ocean satellite and the Indian Ocean satellite (elevation angles of about 50 degrees and 10 degrees from Guam) to get information on this aspect of equatorial scintillation. This report covers measurements made from about the middle of March to the middle of August 1978. Measurements are continuing to be made and they will be included in an updated report.

1. NELC TR 1875, Effects of Equatorial Scintillation Fading on SATCOM Signals, by MR Paulson and RUF Hopkins, 8 May 1973
2. NOSC TR 113, Spatial Diversity Characteristics of Equatorial Scintillation, by MR Paulson and RUF Hopkins, 2 May 1977

## MEASUREMENT TECHNIQUE

The amplitude of broadcast signals from each of the satellites was recorded 24 hours a day on strip chart recorders. During periods of scintillation the recorders were run at 12 inches per hour. Time marks were automatically put on the charts by a time code generator. At irregular intervals, calibration curves were run for each of the receivers.

## DATA PRESENTATION

Starting times and ending times for scintillation with fades greater than 6 dB were read from the charts. These have been plotted in figure 3 for the Pacific Ocean satellite and in figure 4 for the Indian Ocean satellite to show periods of significant scintillation. The lower case "x" on the plots denotes days of missing data. Missing data days were due to equipment malfunctioning or missing charts. On days with neither an x nor a time interval indicated, there was no scintillation. The periods of scintillation were also totalled for each day and the results are shown in figure 5 for the Pacific Ocean satellite and in figure 6 for the Indian Ocean satellite.

## COMMUNICATIONS OUTAGE VS SCINTILLATION

Personnel at the satellite terminal in Guam have been keeping a daily record of uhf communications outages for each of the satellites which appear to have been caused by scintillation. Figure 7 shows a plot of these outages for the months of April and May 1978. In figure 8, the reported outages for the Indian Ocean satellite are plotted as a function of the daily occurrence of scintillation as shown in figure 6. A correlation between the two showed a value of 0.84. A one-to-one correspondence between communications outages and scintillation would have occurred if all the points fell on the dashed line shown in figure 8. Most of the points are seen to be somewhat above this line. A possible explanation for this could be that scintillation with fades less than 6 dB could be causing some outages.

## OCCURRENCE OF SCINTILLATION VS SOLAR ACTIVITY

It is generally accepted that the occurrence, intensity, and duration of equatorial scintillation vary directly with the 11 year solar cycle. Using a common 11 day period for 4 different years, Paulson and Hopkins<sup>2</sup> showed a direct dependence of the occurrence of scintillation on both the sunspot number and the 2800 MHz solar flux. The curve showing the dependence on the 2800 MHz solar flux is reproduced in figure 9 with the data points marked 1970, 1971, 1972, and 1976 and a straight line approximation drawn. No direct day-by-day correlation was observed, however.

To see how the present 1978 data would fit this curve, the occurrence of scintillation data and the solar flux data were averaged for successive 11 day periods where the data permitted and the results plotted on the same figure (fig 9) as data points one through nine. Seven of the nine points are above the line. Furthermore, there is a considerable scatter in the points. Both of these conditions may be the result of a seasonal variation

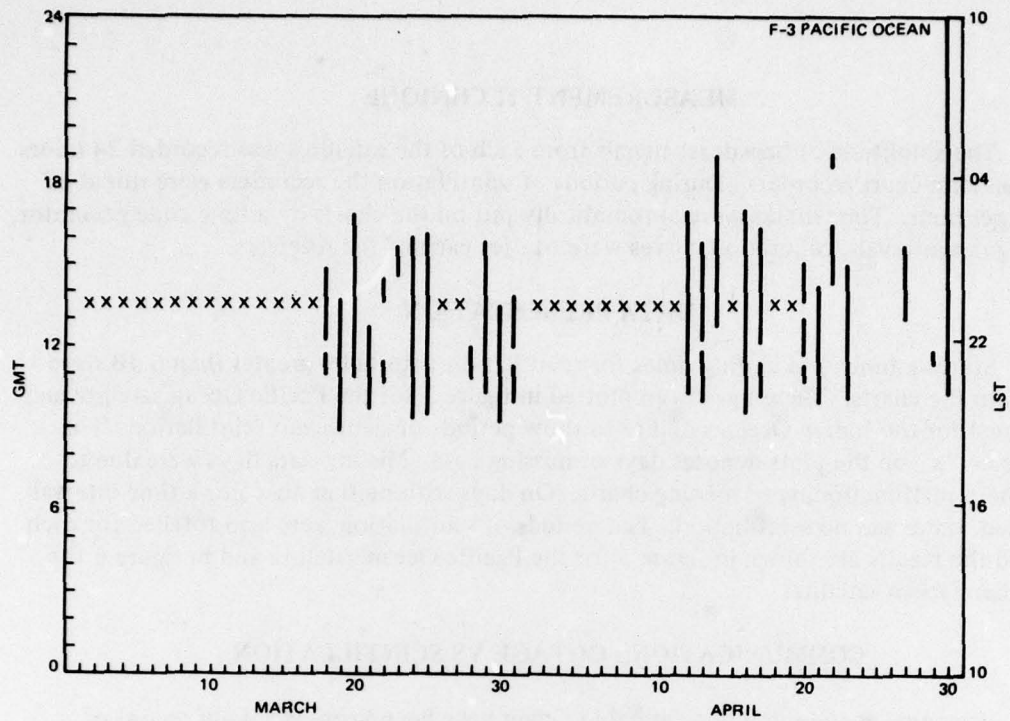


Figure 3. Periods of scintillation occurrences with fades greater than 6 dB below the undisturbed signal at Guam - Pacific Ocean satellite.

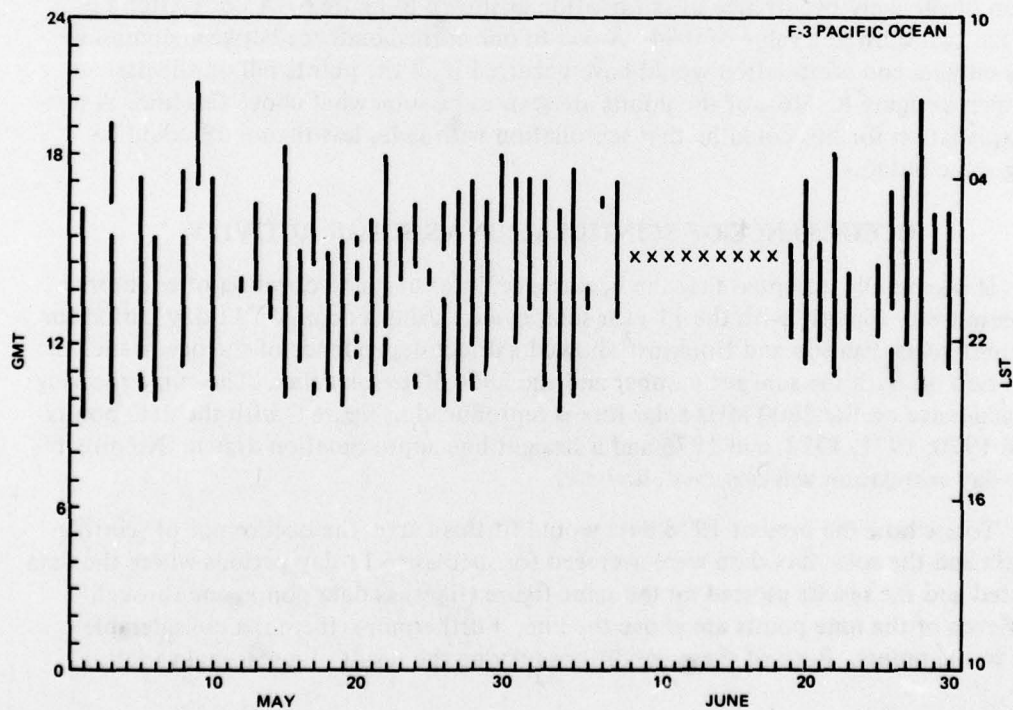


Figure 3. (Continued).



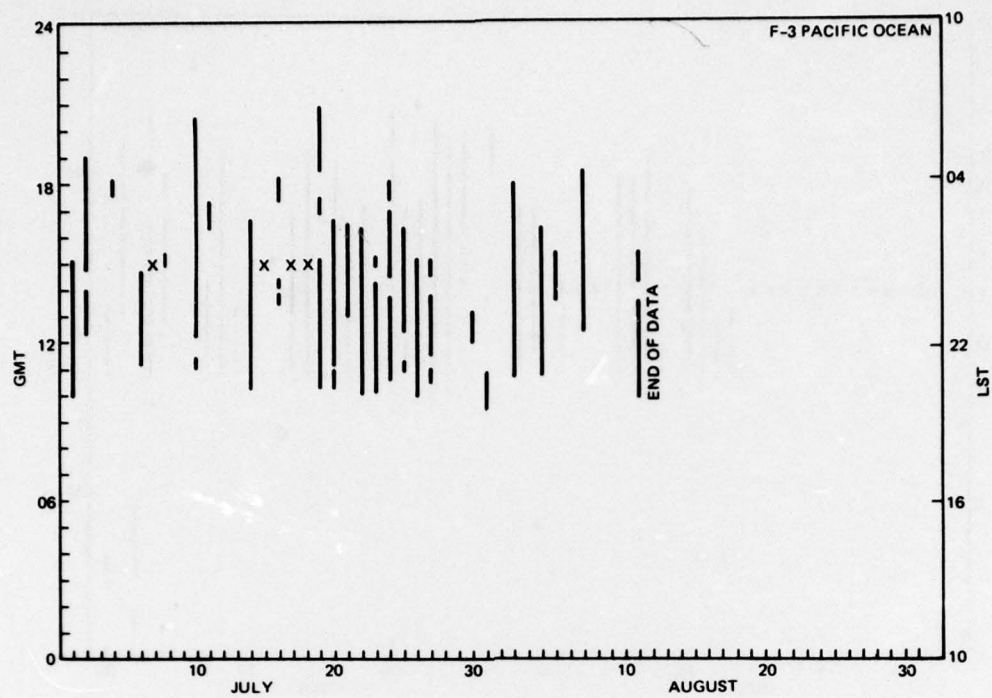


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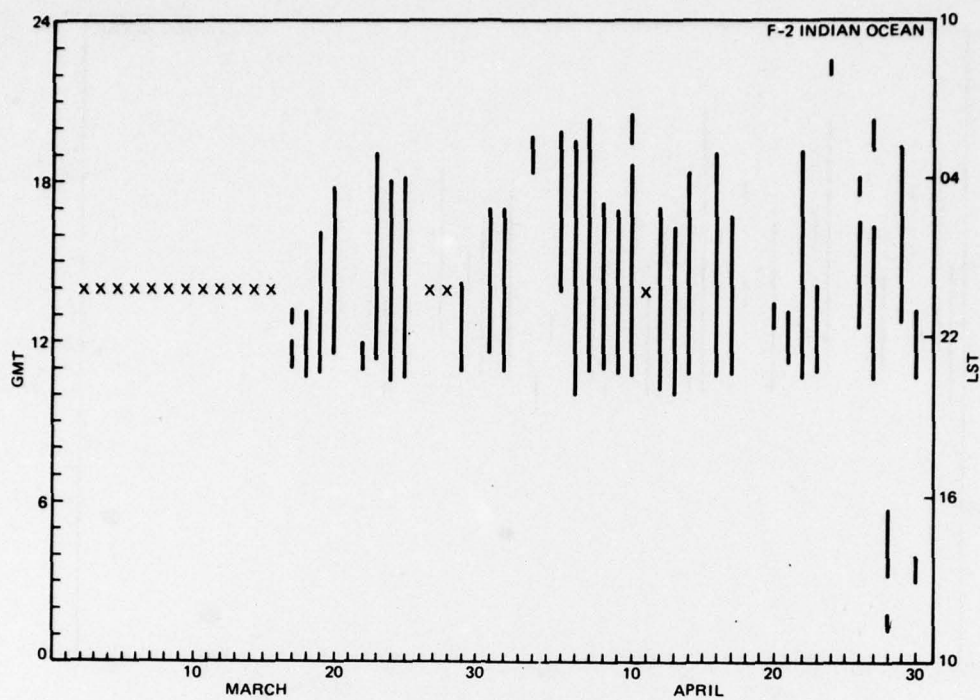


Figure 4. Periods of scintillation occurrences with fades greater than 6 dB below the undisturbed signal at Guam - Indian Ocean satellite.

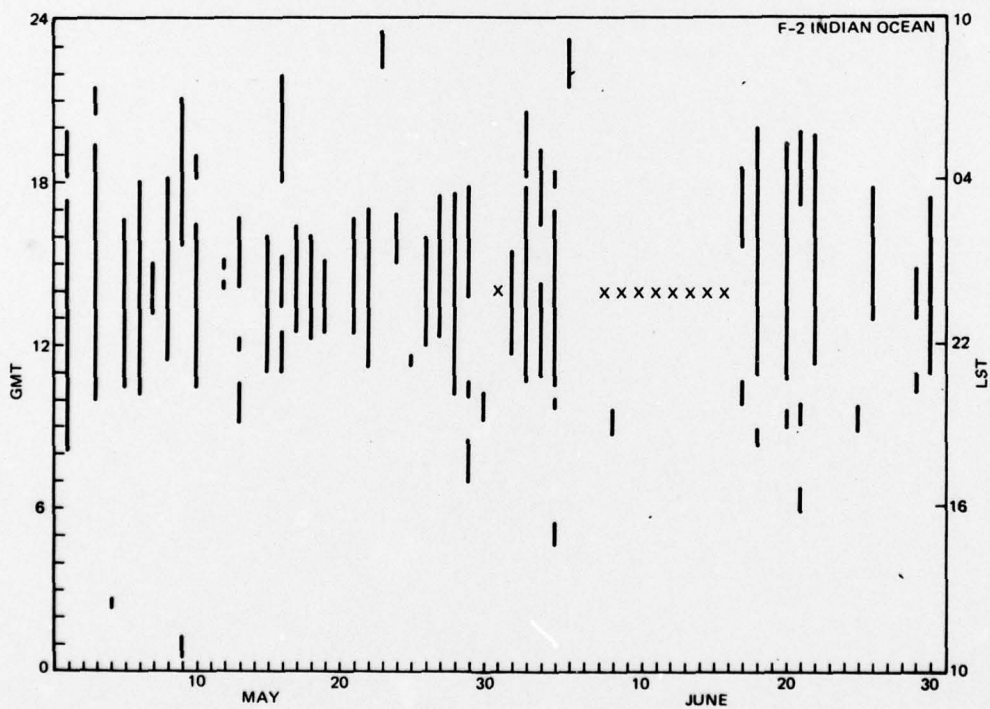


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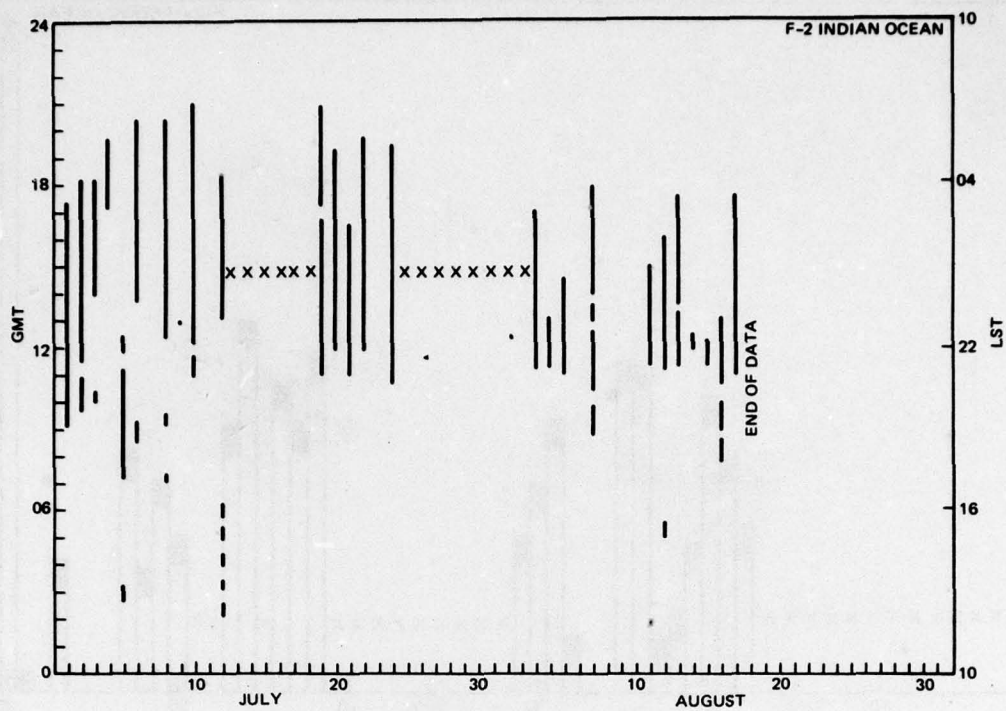


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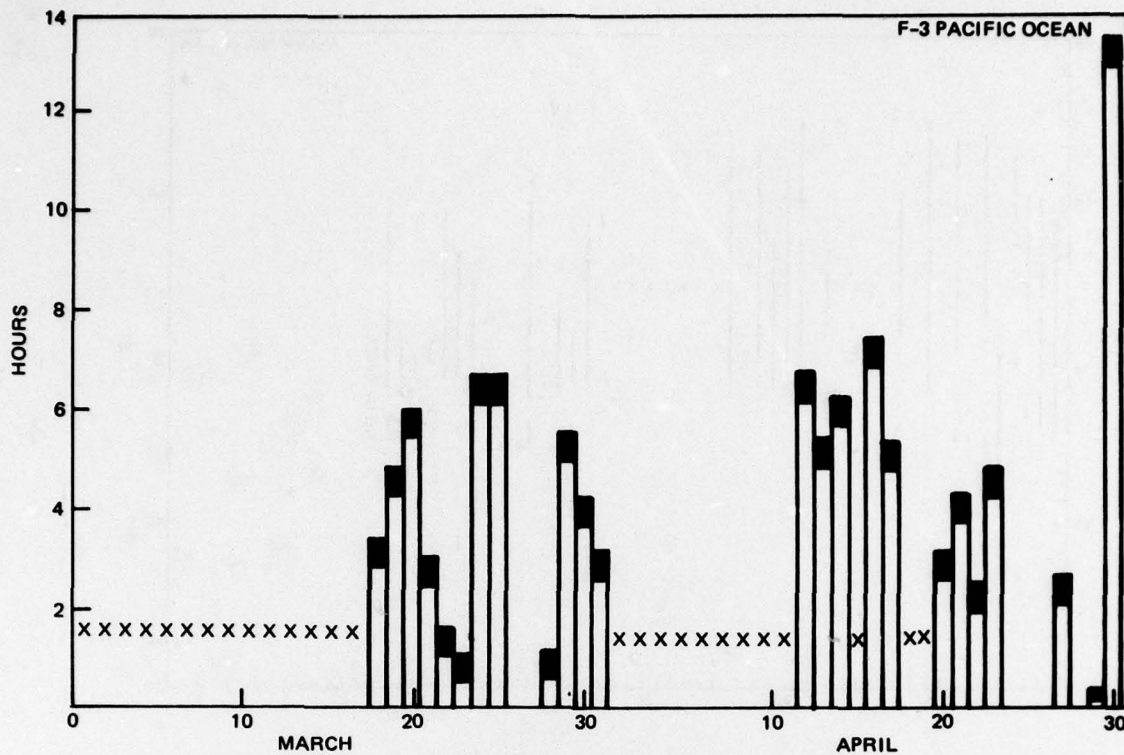


Figure 5. Daily total hours of scintillation with fades greater than 6 dB – Pacific Ocean satellite.

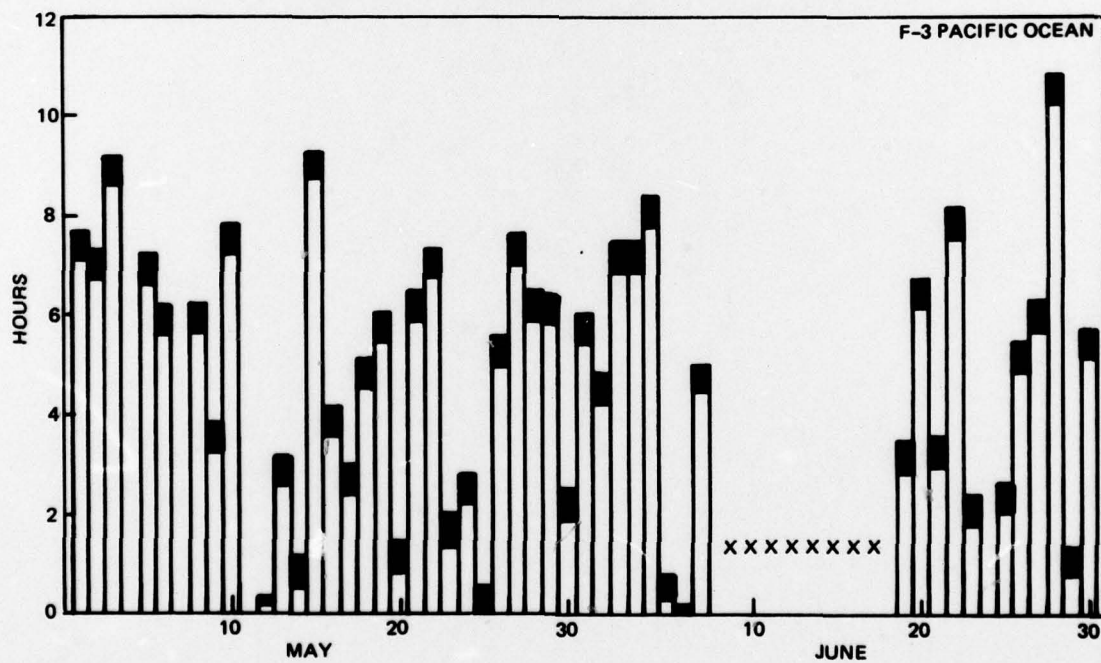


Figure 5. (Continued).



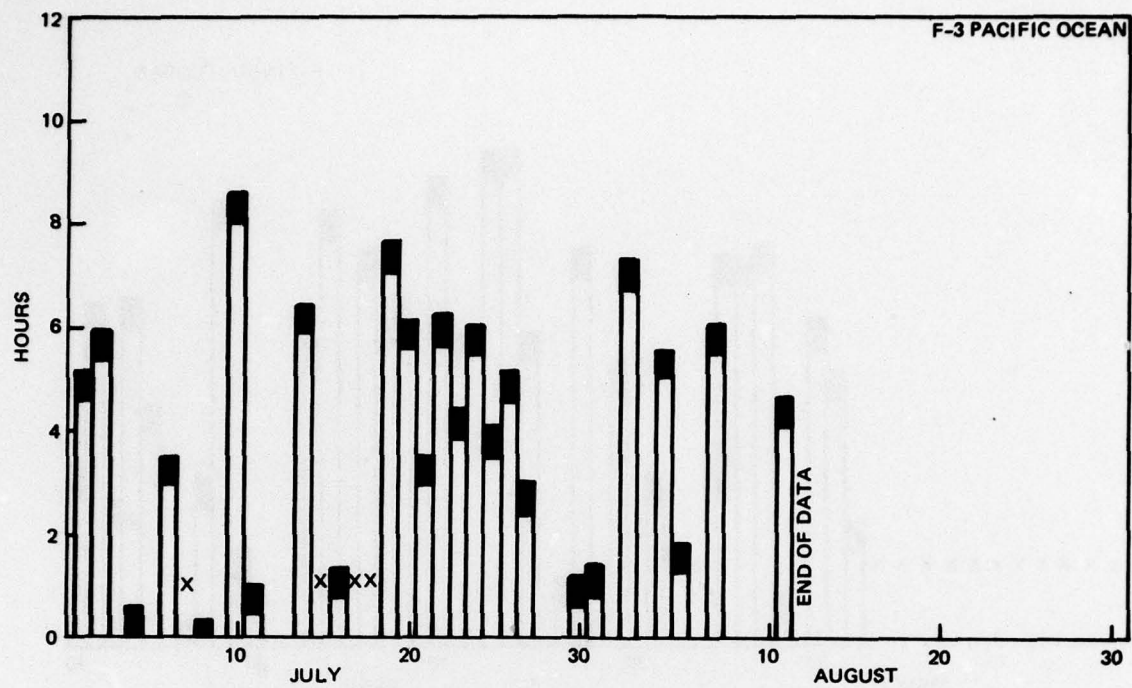


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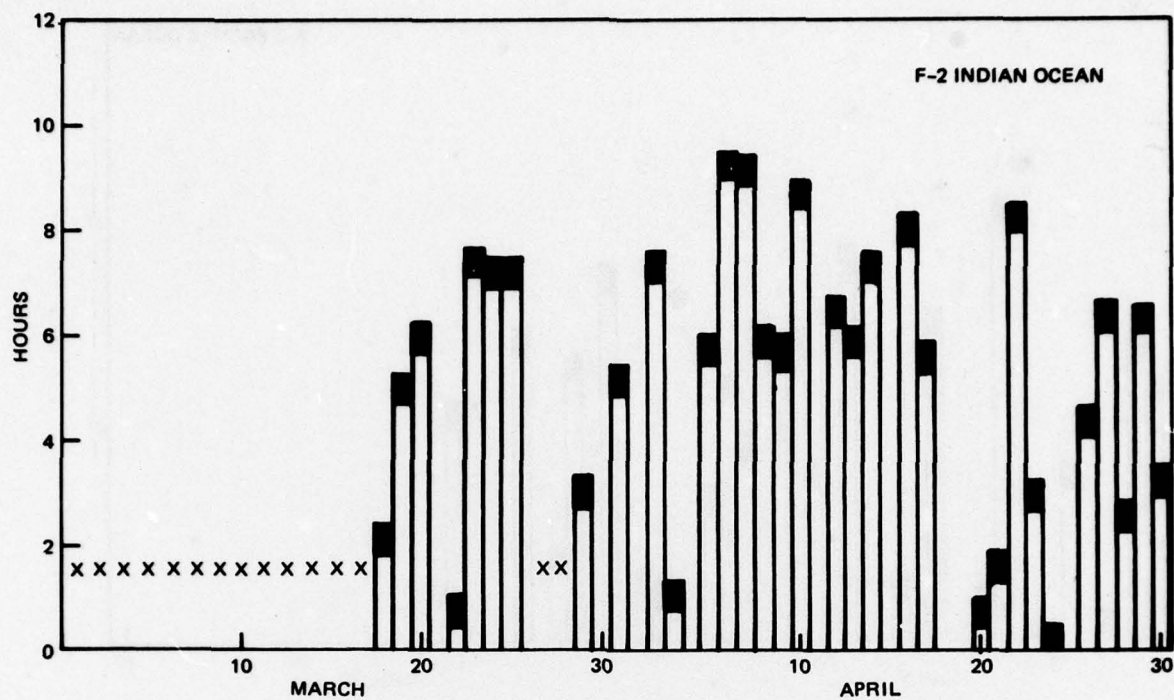


Figure 6. Daily total hours of scintillation with fades greater than 6 dB – Indian Ocean satellite.

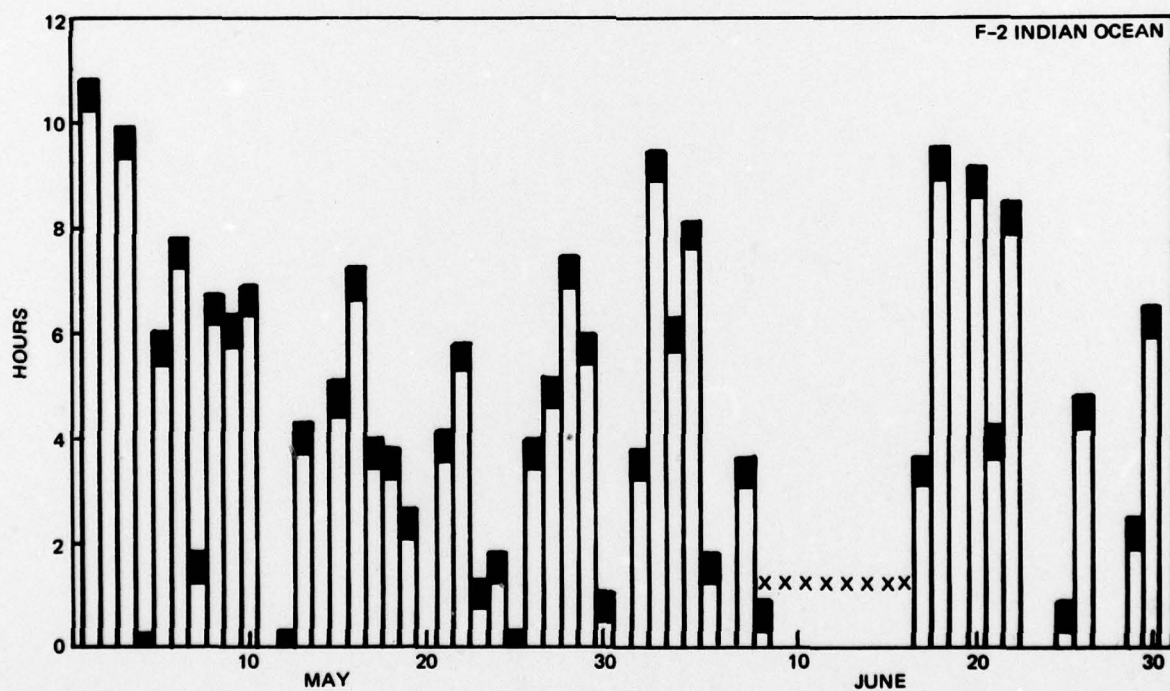


Figure 6. (Continued).

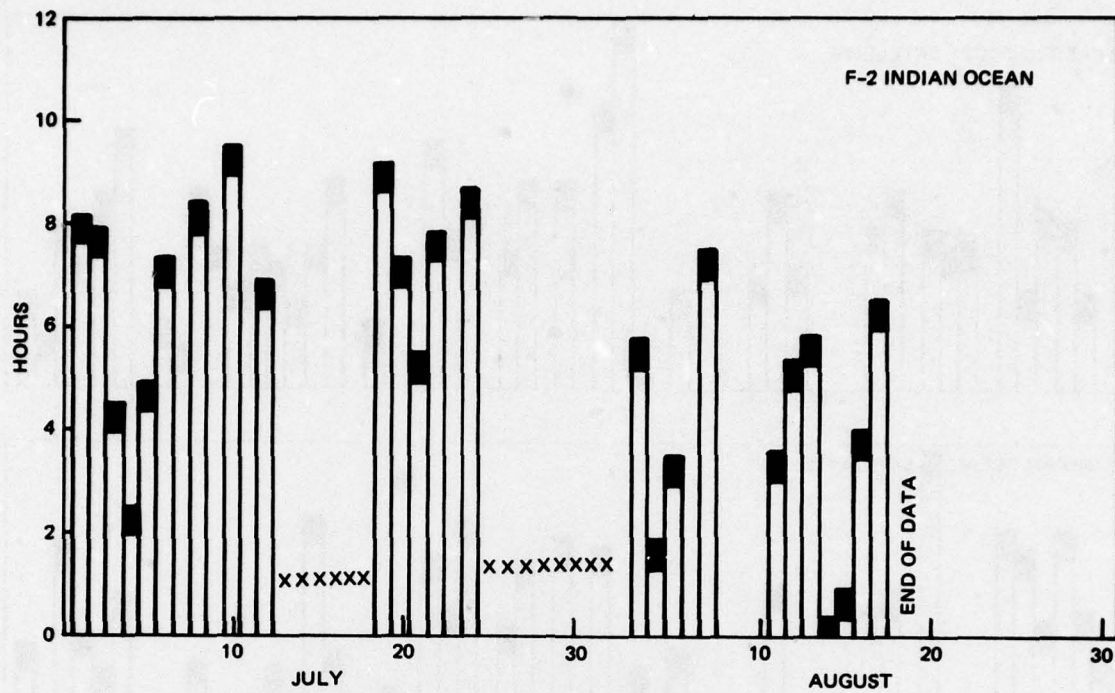


Figure 6. (Continued).

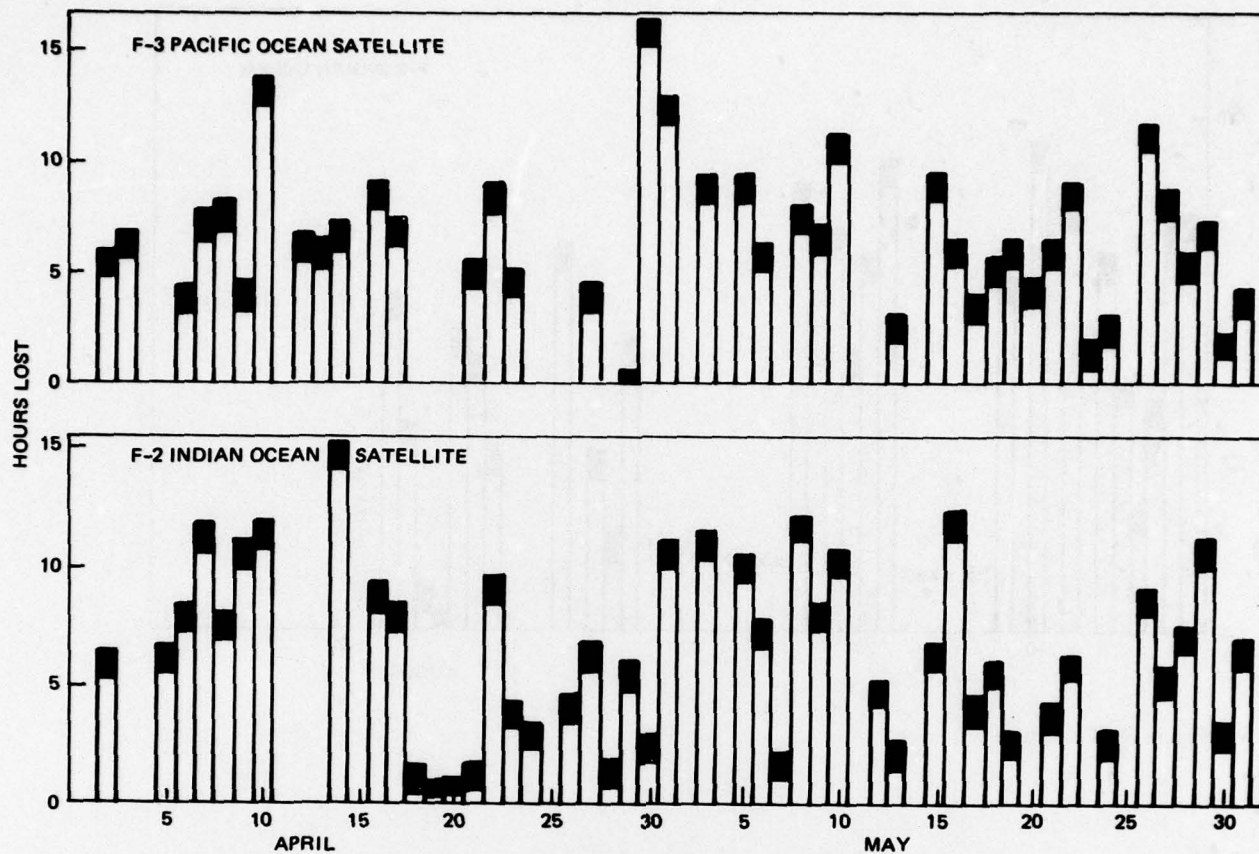


Figure 7. Daily hours of operation lost due to scintillation at Guam.



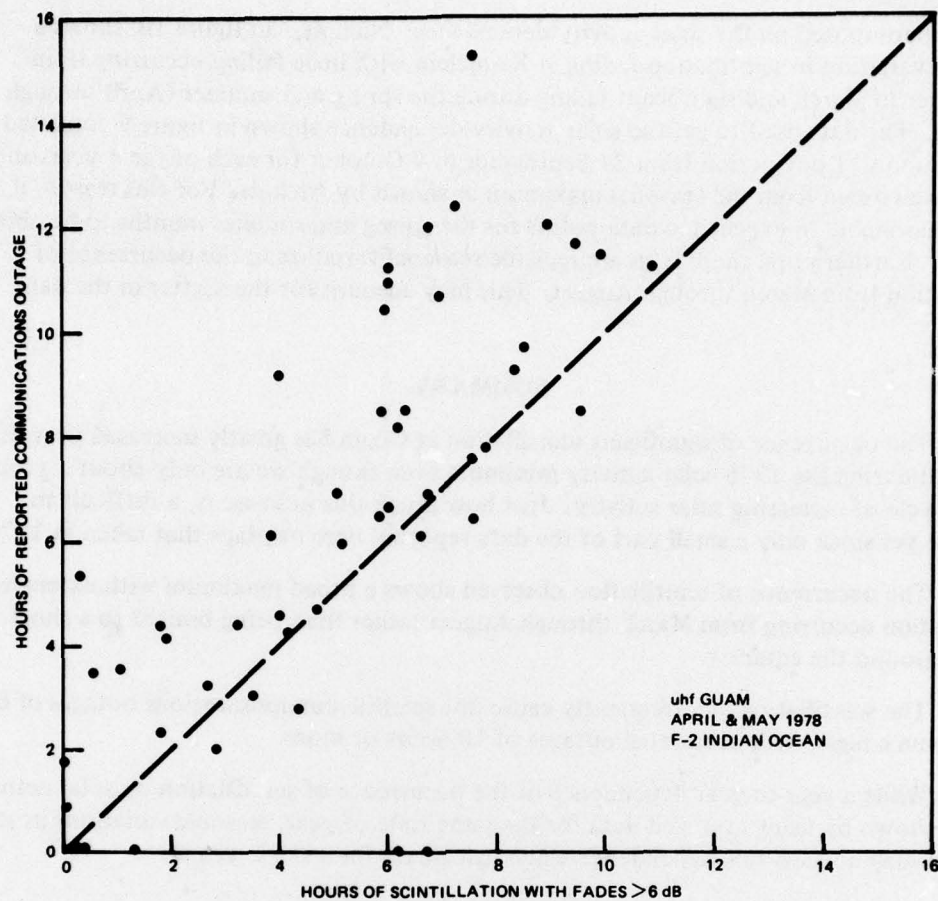


Figure 8. Comparison of reported communications outage with occurrence of scintillation for the Indian Ocean satellite.

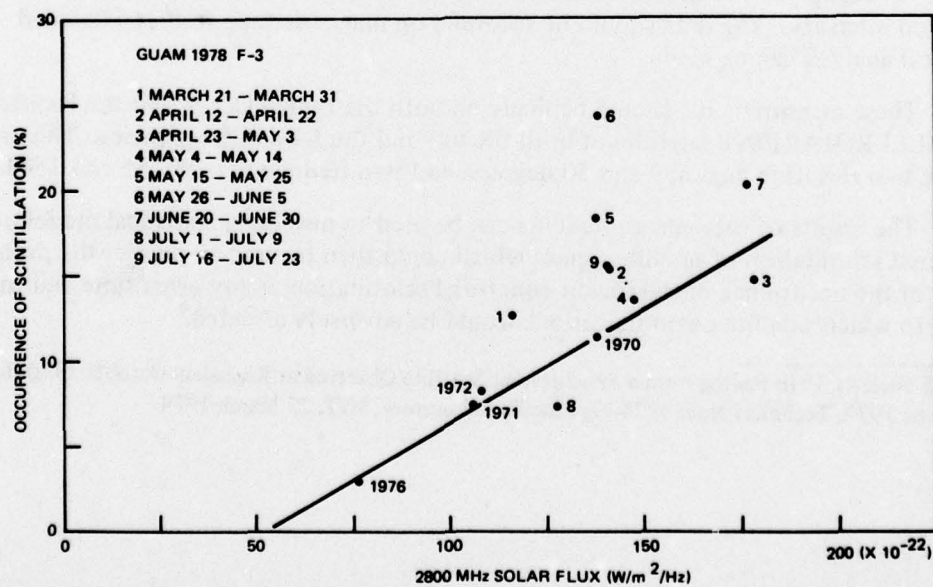


Figure 9. Occurrence of scintillation compared to the 2800 MHz solar flux for the Pacific Ocean satellite.



being superimposed on the solar activity dependence. Nichols,<sup>3</sup> in figure 10, shows a seasonal variation in scintillation fading at Kwajalein with little fading occurring from November to March and significant fading during the spring and summer (April through August). The data used to get the solar activity dependence shown in figure 9 consisted of a common 11 day period from 24 September to 4 October for each of the 4 years shown. This is well down from the seasonal maximum as shown by Nichols. For this reason, it seems reasonable to expect the data points for the spring and summer months to be above the line. Furthermore, there is an appreciable seasonal variation in the occurrence of scintillation from March through August. This may account for the scatter in the data points.

### SUMMARY

The occurrence of significant scintillation at Guam has greatly increased over that observed during the 1976 solar activity minimum even though we are only about 2 years into a cycle of increasing solar activity. Just how much this increase is, is difficult to evaluate yet since only a small part of the data reported here overlaps that taken in 1976.

The occurrence of scintillation observed shows a broad maximum with extensive scintillation occurring from March through August rather than being limited to a short period around the equinox.

The scintillation can frequently cause uhf satellite communications outages of 6 to 8 hours a night with occasional outages of 10 hours or more.

While a year-to-year dependence of the occurrence of scintillation on solar activity can be shown by using averaged data for the same time of year, seasonal variations in scintillation may conceal this dependence when using data for a single year.

### RECOMMENDATIONS

Equatorial scintillation measurements should be made at Guam for a longer period of time, at least a year, to get information on the seasonal variation in scintillation occurrence and intensity. The data should be recorded on magnetic tape so that a detailed statistical analysis can be made.

These measurements should be made on both the Indian Ocean and the Pacific Ocean GAPFILLER/MARISAT satellites at both the uhf and the L-band frequencies. This would provide two elevation angles, 9 and 50 degrees, and two frequencies, 257.55 and 1541.5 MHz.

The results of these measurements can be used to develop a statistical model of equatorial scintillation of satellite signals which could then be used to predict the probability of the occurrence of significant equatorial scintillation at any given time and the extent to which satellite communications would be adversely affected.

3. BE Nichols, VHF Fading from a Synchronous Satellite Observed at Kwajalein October 1970 through June 1972, Technical Note 1974-19, Lincoln Laboratory, MIT, 22 March 1974

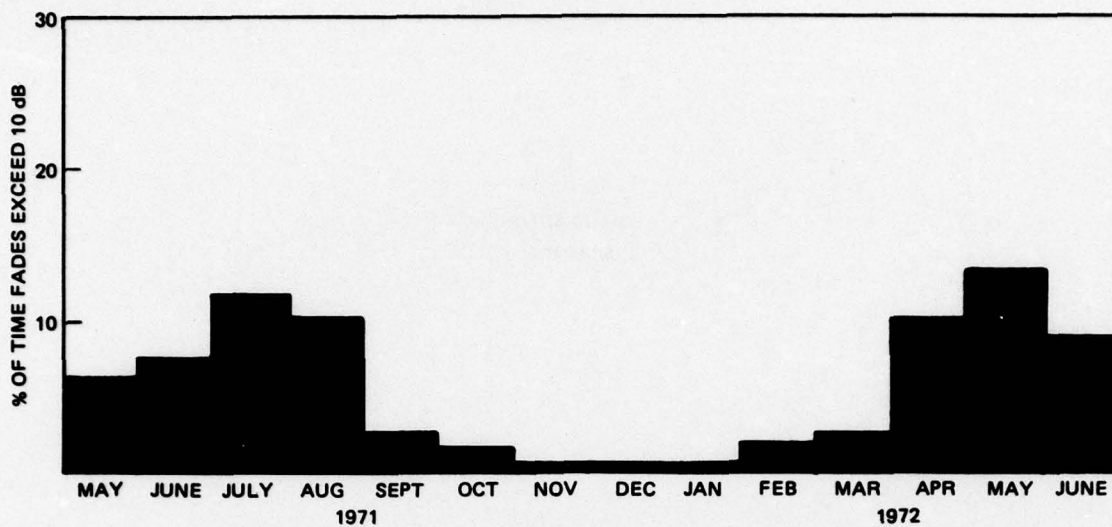


Figure 10. Occurrence of scintillation at Kwajalein with fades greater than 10 dB (Nichols - ref 3).